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AFMTC-TR-57-25
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OERLIKON

FINAL ENGINEERING REPORT
FOR
IGOR SHELTERS

Contract AF 08(606)-1[illegible]

OERLIKON TOOL & ARMS CORPORATION OF AMERICA
ASHEVILLE NORTH CAROLINA

AFMTC-TR-57-25
AD 124147.

FINAL ENGINEERING REPORT

For

IGOR SHELTERS

This Report Covers the Period
May 28, 1956 to July 30, 1957

Oerlikon Tool & Arms Corporation
of America

Asheville, North Carolina

Air Force Missile Test Center (ARDC)
Patrick Air Force Base, Florida

Contract AF 08(606)-1212
28 May, 1956

Date of Report: July 31, 1957

ABSTRACT

This Report is the Final Engineering Report covering work completed on the IGOR Shelter under Contract AF 08(606)-1212. Data and Calculations are included to indicate the completed shelters conform to the design requirements as set forth in the Technical Exhibit No. SE/862-571B.

PART I

1. PURPOSE.

The purpose of this contract was to design, develop, and fabricate six (6) IGOR Shelters in accordance with Technical Exhibit SE/862-571B, dated May 23, 1956. The IGOR Shelter consists of the following parts:

A. A Circular Base Section

B. An Upper Rotating Section

C. A Power Drive Unit for controlling and rotating the Upper Rotating Section.

2. GENERAL FACTUAL DATA.

2.1. Identification of Engineers and Technicians.

2.1.1. Chief Engineer. Mr. T. C. Burnette, Jr., had responsibility for the basic design of the IGOR Shelter.

2.1.2. Project Engineer. Mr. C. C. Culler had responsibility for the developmental design.

2.1.3. Administrator. Mr. John L. Nichols had responsibility for administrative work after December, 1956.

2.1.4. Manufacture and fabrication was carried out at the Murfreesboro, Tennessee, plant of the Alfred Hofmann & Co., of West New York, New Jersey. Mr. V. E. Fortuna, of the Alfred Hofmann company, had responsibility for this work.

2.1.5. Design Engineer. Mr. Pat Ingelse had responsibility for detail drawings.

2.1.6. Electronic Engineer. Mr. W. R. Peck had responsibility for the servo drive.

2.1.7. Summary of work effort. Mr. T. C. Burnette, Jr., left the Contractor's employ as of January 1, 1957, and Mr. John L. Nichols took over the administrative duties. The Alfred Hofmann company completed and shipped the first three shelters by April 3, 1957, and the remaining three shelters were completed and ready for inspection on April 29, 1957. They were accepted by the Technical Representative of the Contracting Officer on July 12, 1957, and shipped on July 19, 1957.

2.2. Patents.

2.2.1. The Power Drive Unit for controlling and rotating the Upper Rotating Section is identical electronically to the power drive units supplied with Oerlikon proprietary rotating domes. A patent application, Serial No. 519,390, filed July 1, 1955, with the assigned name, "Thyratron Control System," covers the electronic circuitry in the Power Drive Unit.

3. DETAIL FACTUAL DATA.

3.1. Preliminary Design.

The preliminary design was approved by the Contracting Officer in July, 1956.

3.2. Final Design.

3.2.1. Circular Base Section. The final design of the Circular Base Section was completed in September. The actual construction details of importance are as follow:

A. Circular Base Section was built as an integral unit, as it was possible to ship it to Patrick Air Force Base as a single unit.

B. The Circular Base Section has a rolled 3" x $2\frac{1}{2}$" x 3/8" aluminum angle forming a circular track on which the Upper Rotating Section rotates. Twelve (12) vertical supports of 3" x 1/4" Zee aluminum channel support the circular track and provide mounting surfaces for the aluminum skin which forms the inside and outside vertical surfaces of the Circular Base Section. Aerocor Fibreglas insulation, with a nominal thickness of 3", placed between the aluminum skins provides the required thermal insulation.

C. The Circular Base Section has an annex approximately 5 1/4 feet wide and 2 1/2 feet deep, which encloses the Power Drive Unit. An access door, about 42" wide, is provided in the Circular Base Section. The Circular Base Section can be mounted to the tower by using the eight (8) 1" diameter bolt holes equally spaced on a 13 ft. 5 in. diameter circle. Metal shims should be placed under each vertical support during installation as required to level the circular track.

3.2.2. <u>Upper Rotating Section</u>. The final design of the Upper Rotating Section and its associated parts was completed in October; however, numerous changes were made as required for optimum performance as the No. 1 Shelter was being assembled. The last of these changes was made in February, 1957. The construction details of importance follow:

A. The structural shape of the Upper Rotating Section was fixed by rolled 1 3/4" x 3" x 1/8" aluminum rectangular tubing formed and welded in the desired shape and location. The shaped surfaces of the Upper Rotating Section are of a sandwich construction consisting of three inches of Dow Styrofoam #33 bonded between an outside and an inside layer of fiberglass. The fiberglass layers are also bonded to the rectangular tubing producing a unified structure.

B. The primary support member of the Upper Rotating Section is the guide and support ring assembly. The guide ring is a rolled 3/8" x 10" aluminum plate welded to the support ring which is a rolled 3 1/2" x 2 1/2" x 1/4" aluminum angle. The six (6) support rollers, the six (6) lockdown rollers, and the six (6) counter-rollers, and the six (6) positioning rollers are mounted upon the guide ring.

C. There is a large viewing aperture, about 6 1/2 ft. wide and having a 105° arc, with two removable doors in the Upper Rotating Section. The lower, smaller door can ride piggy-back on the upper, larger door. The upper, larger door is motorized with limit stops at the upper and lower limits of travel.

3.2.3. <u>Power Drive Unit</u>. The final design of the Power Drive Unit was completed in September, 1956. The important details are as follow:

A. A roller chain is stretched around the guide ring over 3/8" spacers and is held to the guide ring by chain attachments located at approximately 3 degrees around the guide ring. A mating link-belt sprocket has a 60:1 ratio with the Upper Rotating Section. Due to the type of construction, the guide ring will not be a perfect circle, and therefore the sprocket shaft cannot be rigidly fixed. A kinematic type drive, pivoting about the drive motor axis, has been provided to allow the sprocket shaft to move in and out as required by the guide ring. An adjustable sprocket counter-roller has been provided to roll against the inside surface of the guide ring to maintain the sprocket in the roller chain at all times.

B. The drive motor is a 3/4 horsepower D.C. motor with a rated speed of 1200 rpm. With the gear ratios as provided, the dome will rotate at least 25 degrees/second and will track up to at least 20 degrees/second. The shelter synchro control transformer is geared to the sprocket shaft to turn at exactly a 1:1 ratio to the shelter. This synchro is a Doelcam 23CT6 and mates with a Doelcam 23CX6 to be mounted in the IGOR instrument.

C. Access to the Power Drive Unit is provided through the inside annex cover plate, which is removable by means of Dzus fasteners. All the electronic adjustments can be made at the electronic control unit panel located to the right of the inside surface of the annex.

D. The Power Drive Unit requires only 117 volt, 60 cycles per second, single phase power. The single power inlet supplies all the lights located in the Circular Base Section, the convenience outlets, the Reel-lite, and the Power Drive Unit. The power source must be connected to the inlet terminals of the fused switch box in the left-hand corner of the annex as viewed from inside the dome.

3.3. Thermal Properties of the Shelter.

3.3.1. Circular Base Section Insulation. The contract called for heat insulating lining to be equivalent to 3" of fiberglass. Three inches of Aerocor Fibreglas were used to insulate the Circular Base Section. In the annex, at least one inch of Aerocor Fibreglas was used on all surfaces, and two inches were used wherever possible.

3.3.2. Upper Rotating Section. The Dow Styrofoam #33 used in the shelter has a k factor slightly better than the k factor of fiberglass, and thus the 3 inches of Styrofoam with the fiberglass bond has better insulation capabilities than 3 inches of fiberglass.

The doors covering the viewing aperture have only two inches of Aerocor Fibreglas with aluminum reflector surfaces. Original design had doors 3 inches thick, but the weight of the doors was excessive, and a compromise was made between weight and thermal insulation.

3.4. Structural Data.

3.4.1. Exhibit I presents calculations made in January, 1957, determining the critical stresses in the IGOR Shelter for winds of 130 miles per hour when the viewing aperture is closed and for gusts of 70 miles per hour when the viewing aperture is open.

3.5. Acceptance Inspection and Testing.

3.5.1. Exhibit II is the Acceptance Inspection and Testing Report of the AFMTC Technical Representative covering the first three shelters. In the acceptance inspection, the requirements of the contract, as stated in the AFMTC Technical Exhibit No. SE/862-571B, are compared to the IGOR Shelters as supplied. The deficiencies noted were corrected before shipment of the No. 1, No. 2, and No. 3 shelters. The seal leakage tests were carried out on these shelters on March 5 and 6, 1957, and there was no evidence of leakage. See Exhibit III.

3.5.2. The test results of the IGOR Shelters, as recorded in Exhibit II, determine the Power Drive Unit performance. This data indicated a low acceleration in the counter-clockwise direction of the No. 1 shelter.

3.5.3. Exhibit III summarizes the adjustments and changes made on the No. 1 Dome Control Unit to improve its performance in the counter-clockwise direction. The 30-degree step input test indicates the performance is the same in both directions after the adjustments were made.

3.5.4. Exhibit IV is the test results of the Power Drive Unit performance for the No. 4, No. 5, and No. 6 shelters. The data for Shelter No. 5 indicated an acceleration below 10 degrees per second per second.

Exhibit V is the test results of the Power Drive Unit performance for the No. 5 Shelter, recorded the week before the shelters were shipped.

3.6. Motorized Door.

3.6.1. Due to the size and weight of the Viewing Aperture Door, it was desirable to have some automatic means of raising and lowering the door. A 1/4 horsepower gear motor was mounted at the center of the upper edge of the Viewing Aperture to move the doors up or down in response to push-button controls. Limit switches are provided to stop the doors at the desired extremities of travel.

3.7. Neoprene Sheet Seal.

3.7.1. Experience with the first three units which were shipped to Patrick Air Force Base indicated that the wind conditions existing there made the oil seal undesirable. In order to effect a seal without major changes being required, the Neoprene Sheet Seal was added at the base of the Upper Rotating Section. This seal must be manually raised for operation and must be manually lowered to seal the Shelter in the stowed condition. The oil seal may or may not be used in conjunction with this Neoprene Sheet Seal, as the operating personnel so desire.

Exhibit VI is the agreement defining the requirements for the Neoprene Sheet Seal made between Oerlikon Tool & Arms Corporation of America and AFMTC.

PART II

1. CONCLUSIONS.

1.1. Styrofoam Fibreglas Construction.

The Styrofoam Fibreglas sandwich type construction has the characteristics desired for Astrodome Shelters. Its thermal insulation properties are the best available. Its rigidity and strength to weight ratio is high. Its fabrication process is versatile, permitting many different shapes and sizes. Its weathering properties are excellent. Any accidental breaks in the exposed surfaces can be easily repaired with a minimum of equipment.

1.2. Kinematic Action Power Drive.

The Kinematic Action drive mechanism presents some definite advantages for driving Astrodome Shelters. Its basic purpose is to allow non-circularity and eccentricity of the rotating section while maintaining a rigid and accurate gearing between the drive shaft and the rotating section. The drive as assembled in the IGOR Shelters is protected from the outside weather conditions. The friction level of this drive is quite low and allows in and out movements of the sprocket shaft of two inches.

1.3. Rotating Mass and Friction Level.

The rotating mass of the IGOR Shelter is in excess of 1300 pounds and has a Wr^2 of 54,600 #-ft.^{2}. The friction level was reduced by using stainless steel-tired ball bearing rollers. The shelters as built with the electronically controlled 3/4 horsepower motor has an acceleration-velocity product of at least 10 x 25 = 250. Thus, this shelter, or a shelter with similar friction levels and rotating mass, can have this acceleration-velocity product with the same size drive motor. A 1 1/2 horsepower motor would give an acceleration-velocity product of 500. The desired velocity-acceleration ratio can be obtained by selecting the correct gear ratio between the drive motor and the rotating section. The IGOR Shelters as built have a ratio of 206:1 giving a velocity to acceleration ratio of 2.5:1.

EXHIBIT I

STRUCTURAL DATA ON IGOR SHELTER

1. DRAG AND LIFT FORCES ON IGOR DOME AT 130 MPH AND 70 MPH WINDS.

1.1. Drag Force Formula.

Reference for all formulae is Mark's MECHANICAL ENGINEERS' HANDBOOK, Fifth Edition, pp 1468 - 1486.

$$\text{Drag} = C_D \rho \frac{V^2 S}{2}$$

where: ρ = air density = 2.378×10^{-3} pounds/cubic foot
V = wind velocity = 130 mph = 190.6 feet/second
S = surface area

1.2. Drag coefficient C_D.

The dome when stowed presents a surface which is made up of a cylinder and a sphere. Since the dome is a closed volume, the Reynolds number has an effect on the drag coefficient C_D.

$$R = \text{Reynolds } \# = \frac{Vl}{\mu}$$

where: l = length of object perpendicular to air flow in feet $\cong$ 14 ft.
μ = viscosity of air
= 1.21×10^{-5} pounds/foot-second.

at 130 MPH wind:

$$R = \frac{(2.378 \times 10^{-3})(190.6)(14)}{1.21 \times 10^{-5}} = 5.24 \times 10^5$$

at 70 MPH wind:

$$R = (5.24 \times 10^5)\frac{(70)}{130} = 2.82 \times 10^5$$

For sphere drag coefficient is about:

$$C_{D_{Sphere}} \cong 0.4 \text{ at 130 MPH wind}$$

$$C_{D_{Sphere}} \cong 0.5 \text{ at 70 MPH wind}$$

For cylinder with length of 5 diameters and its axis normal to the wind the drag coefficient is:

$C_{D_{cylinder}} \cong .8$ at 130 MPH wind

$C_{D_{cylinder}} \cong .8$ at 70 MPH wind

For cylinder with length of 1 diameter and its axis parallel with the wind the drag coefficient is:

$C_{D_{cylinder}} \cong .91$ at 130 MPH wind

$C_{D_{cylinder}} \cong .91$ at 70 MPH wind

When the dome is in operation, the viewing aperture will be open. The drag coefficient will depend on the location of the opening of the viewing aperture with respect to the wind direction. For the case of maximum drag, the wind would be blowing directly into the opening. The drag coefficient for an open hemisphere facing the wind is:

$C_{D_{open\ hemisphere}} = 1.35$

1.3. Drag forces.

1.3.1. When the shelter is closed and the axis of the cylindrical section is parallel to the wind direction, the surface is a combination of a sphere and a cylinder, and the surface of the spherical portion is:

$S_{sphere} \cong (6)^2 \frac{\pi}{2} = 56.5$ square feet

$S_{cylinder} \cong (8.5)^2 \frac{\pi}{2} - 56.5 = 56.8$ square feet

An approximate drag coefficient for the combined surfaces will be assumed to be as follows:

$$C_D \cong \frac{(.91)(56.8) + (.4)(56.5)}{113.3} = \frac{74.3}{113.3} = .657$$

$$F_{D_1} = \frac{(.657)(2.378)(190.6)^2(113.3)}{2} = 3210 \text{ pounds}$$

F_{D_1} is the force on the upper rotating section when stowed in 130 MPH wind whose direction is parallel to the cylindrical section axis.

1.3.2. When the shelter is closed and the axis of the cylindrical section is normal to a 130 MPH wind, the surface is again a combination of a cylindrical surface and a spherical surface.

Cylindrical Surface Area = (6.5)(8.5) = 55.2 square feet

$$\text{Spherical Surface} \cong 2\int_0^{\pi/3} (r \cos\theta\, d\theta)(r\cos\theta - \tfrac{r}{2})$$

$$\cong 2r^2 \left[\frac{\sin\theta \cos\theta}{2} + \frac{\theta}{2} - \frac{\sin\theta}{2}\right]_0^{\pi/3}$$

$$\cong 2r^2 \left[\frac{0.866}{4} + \frac{\pi}{6} - \frac{0.866}{2}\right]$$

$$\cong r^2 \left[\pi/3 - .433\right]$$

$$\cong (42.25)(.614) = 25.9 \text{ square feet}$$

$$F_{D_{cylinder}} = \frac{(.8)(2.378 \times 10^{-3})(190.6)^2(55.2)}{2}$$

$$= 1903 \text{ pounds}$$

$$F_{D_{sphere}} = \frac{(.4)(2.378 \times 10^{-3})(190.6)^2(25.9)}{2}$$

$$= 447 \text{ pounds}$$

$$F_{D_2} \cong 1903 + 447 = 2350$$

1.3.3. With the viewing aperture open and a 70 MPH wind blowing directly into the viewing aperture, the surface is made up of an open surface 8 1/2 feet by 6 1/2 feet and the closed spherical surface of section 1.3.2.

Open Surface = 55.2 square feet

Spherical Surface = 25.9 square feet

$$F_{D_{open}} \quad \frac{(1.33)(2.378 \times 10^{-3})(102.5)^2(55.2)}{2}$$

$$= 920 \text{ pounds}$$

$$F_{D_{spherical}} = \frac{(.4)(2.378 \times 10^{-3})(102.5)^2(25.9)}{2}$$

$$= 129 \text{ pounds}$$

$$F_{D_3} = 1055 \text{ pounds}$$

The maximum drag force is 3210 pounds.

1.4. Lift forces.

1.4.1. There are no lift coefficients given which are applicable to the shelter. However, an upper limit can be placed on the lift forces to be equal to one half of the drag force.

1.4.2. The weight of the upper rotating section must be subtracted from the maximum lift force to obtain the net lift force.

$$F_{L_{net}} = \frac{3210}{2} - 1400 = 205 \text{ pounds}$$

2. STRESSES IN THE COUNTER-ROLLERS DUE TO THE LIFT AND DRAG FORCES ON THE IGOR DOME.

2.1. Force on counter-rollers due to the forces on the upper rotating section.

Normally the net lift force will be borne by all six counter-rollers fairly equally, but the [illegible] about the lower edge of the upper rotating section which in the worst case is restrained by two counter-rollers. Therefore, we assume that the total net lift at worst is borne equally by four counter-rollers and that two of these rollers are the rollers which counteract the moment due to the drag forces.

2.1.1. Force on four counter-rollers which are assumed to bear the net lift force is:

$$F_{RL} = \frac{205}{4} \cong 51 \text{ pounds}$$

2.1.2. The centroid of the cylindrical surface is about 4 feet up from the base of the upper rotating section. If the wind pressure was equally distributed over the projected area, then the center of pressure would be located approximately there. From configuration, we know that the maximum pressures will be experienced by the lower center surfaces where the air velocities are the lowest, so the pressure center would be lower. Thus four feet is a good assumed value for the moment arm. The turning moment of the drag force is then:

$M_D = 4 \times 3210 = 12{,}840$ pound feet.

The two active counter-rollers will have a moment arm of about 11 feet for a rotation about the lower rear edge of the upper rotating section. The force on each of these two rollers due to the drag moment is about

$F_{RD} = (1/2)\left(\frac{12{,}840}{11}\right) = 584$ pounds

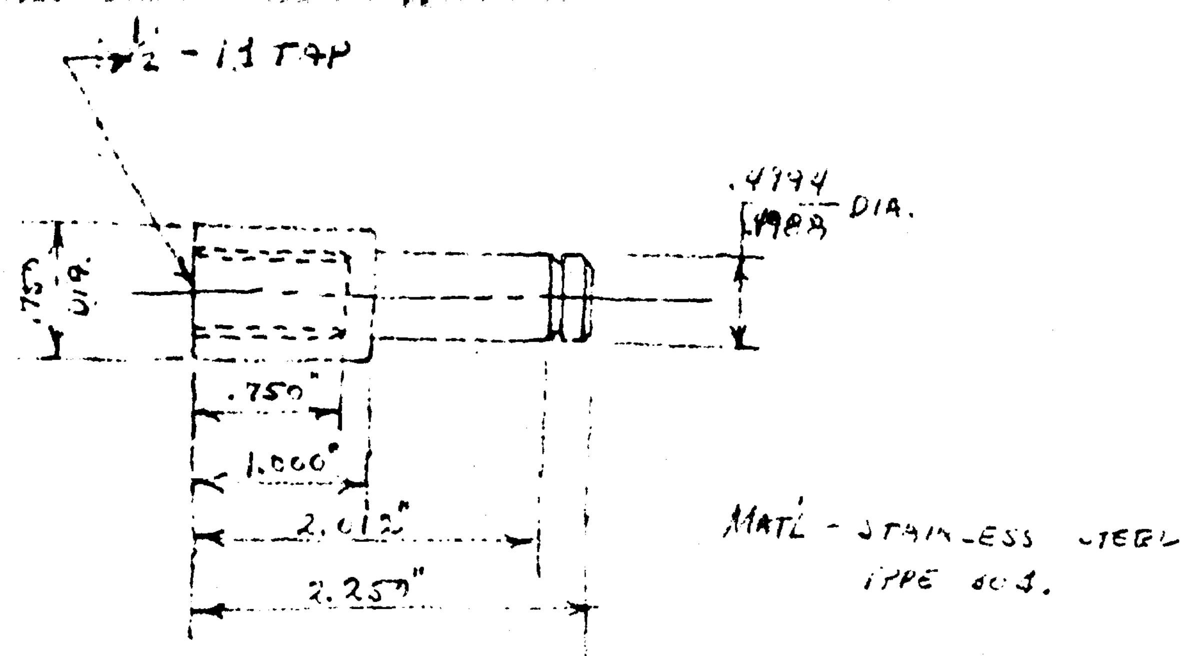
2.1.3. Force on the counter-rollers due to the lock-down rollers is estimated to be about 30 pounds.

2.1.4. Total force on the two maximum loaded counter-rollers is then:

$F_{CR} = 51 + 584 + 30 = 665$ pounds

2.2. Stresses on the counter-rollers.

2.2.1. Counter-roller support shaft is as sketched below:



2.2.2. Shearing stress is a maximum at the 1/2 - 13 mounting bolt. The thread depth is approximately 0.100 inch, so the working area is:

$$A = (.5 - .2)^2 \pi/4 = .0706 \text{ square inches}$$

Shear stress is:

$$S_S = \frac{665}{.0706} = 9410 \text{ psi}$$

2.2.3. The maximum tension stress will occur at the inner edge of the one-half inch nominal diameter portion. The moment on the shaft at that point is:

$$M = (665)(1/2) = 332.5 \text{ pound-inches}$$

The maximum tension stress is therefore:

$$S_T = \frac{4M}{\pi r^3} = \frac{4(332.5)}{\pi(.249)^3} = 27,000 \text{ psi}$$

2.2.4. The material used is stainless steel type 304, which has a tensile strength of 85,000 psi. This gives a safety factor of 3.

3. STRUCTURAL AND MECHANICAL PROPERTIES OF THE FIBREGLASS-STYROFOAM STRUCTURE USED IN THE UPPER ROTATING SECTION.

3.1. Mechanical Properties at 77° F of Styrofoam #33.

Compressive Yield Strength	16 - 38 psi
Tensile Strength	65 - 95 psi
Shear Strength	30 - 40 psi
Flexural Strength	48 - 99 psi

3.2. Mechanical Properties of the Fibreglass-Styrofoam structure as used in the upper rotating section.

Compression Yield Strength (compression normal to the Fibreglass surface) as tested	33 psi
Compression Yield Strength (compression parallel to the Fibreglass surface) as tested	39 - 52 psi
Flexural Strength	180 psi

4. REPRESENTATIVE VALUES OF STRESS IN THE UPPER ROTATING SECTION UNDER LOADING OF 130 MPH WINDS.

4.1. Maximum pressure on dome surface (in terms of increase over atmospheric pressure).

$$P_{max} = 1/2 \rho V^2 = \frac{0.002378}{2} (190.6)^2$$

$$= 43.5 \text{ pounds/square foot}$$

$$= 0.302 \text{ psi}$$

This corresponds to compression loading normal to Fibreglass surface, which has a yield strength of 33 psi.

4.2. If the total force acting on the dome is considered to be acting at the front edge of the upper rotating section and that all restraint is considered acting at the rear edge of the upper rotating section, a mean compressive stress (compression parallel to the Fibreglass Surface) can be calculated for the mid cross section of the dome. The area of this cross section is as follows:

$$A_{cs} \cong 3\left[(2)(78)\left(\frac{\pi}{3}\right) + 2(30) + 66\right]$$

$$\cong 3\left[163 + 60 + 66\right] = 868 \text{ square inches}$$

$$\text{Stress} = \frac{3210}{868} \approx 3.7 \text{ psi}$$

The yield strength for this loading as measured is 39 psi.

4.3. In order to calculate the flexure loading in the dome the problem must be greatly simplified. Since the spherical shape is stronger than the cylindrical shape, we shall assume a cylindrical cantilever beam with an outside radius of 6 1/2 feet and a wall thickness of 3 inches. A concentrated load of 3210 pounds is applied at a distance of 6 feet from the fixed end.

For the beam:

$$\frac{I}{C} = \frac{\pi}{4}\left[\frac{ro^4 - ri^4}{ro}\right] = \frac{\pi}{4\,ro}(ro - ri)(ro + ri)\left[ro^2 + ri^2\right]$$

$$= \frac{\pi}{4(78)}(3)(153)(6084 + 5625) \cong \frac{\pi}{4}(68{,}900) \text{ in.}^3$$

The maximum moment is:

$$M = (3210)(72)$$

The maximum flexural stress is:

$$S_f = \frac{Mc}{I} = \frac{(3210)(72)(4)}{\pi(68{,}900)} = 4.27 \text{ psi}$$

The corresponding flexural yield strength was measured as 180 psi.

In the above assumed conditions, the cylinder would have internal support to hold it in the cylindrical shape. In the actual structure, the aluminum members, the spherical section, and the main support plate tend to maintain the dome in the unloaded shape.

EXHIBIT II

2/25/57

ACCEPTANCE INSPECTION & TEST REPORT

Subject: IGOR Astrodome - W.A. 02-62016

Applicable Documents: Technical Exhibit #SK/862-571B
Contract AF08(606)-1212

Contractors: Oerlikon Tool & Arms Corp. of America (Hereinafter referred to as OTA), Asheville, N.C.

Fabrication By: Alfred Hofmann Co.
Box 438
Nashville, Tenn.

Tests conducted at Alfred Hofmann Co. 11-15 February 1957.

Personnel participating in tests or present at Hofmann during inspection and test period:-

Mr. Vincent Fortuna, Hofmann Plant Manager
Mr. Walter Peck, Engineer, OTA
Mr. John L. Nichols, Asst. to President, OTA
Mr. F. B. Tyler, A.C.O., Atlanta Air Procurement District
Mr. G. B. Cope, Engineer, RCA, AFMTC Technical Representative
Mr. E. Graves, Plant Supt., Production Control, Hofmann
Mr. W. A. Thornberry, Plant Foreman, Hofmann
Prof. W. R. Baker, Associate Professor of M.E., Vanderbilt Univ.

Factual Data: The Technical Exhibit was reviewed by Messrs. Nichols, Peck, Fortuna and Cope. A brief resume follows. The results of this review were later discussed with Mr. Tyler.

3.1:
The required radius of the hemispherical volume should be 6'6" with center 5'8" above floor level and actually is 6'7-1/8" radius with center 5'10-1/4" above floor.

3.1.1:
The weight is estimated to be 2,750 pounds as compared to permissible maximum of 2,500 pounds. Actual weights will be determined at time of shipment. The weight problem on IGOR towers is not critical and weight in excess of 2,500 pounds is acceptable.

3.1.2:
OTA submitted structural data which has been reviewed. The astrodome will withstand 130 MPH hurricane velocity winds as required.

3.1.3:
The required dome aperture width is 6'8" and checks out satisfactorily. This aperture is to permit elevation tracking from approximately -5° to $+95^\circ$ and not obscure the field of view of an 18" aperture telescope. The entire clear aperture (18") can only be used from approximately -3.83° to $+91.5^\circ$. The technical representative advised the contractor that this elevation travel is acceptable. The requirement that the field of view of the sighting telescopes must not be obscured will permit 4.5° dome lag. This item is covered in performance data for each dome and discussed under test procedures.

3.1.3.1:
The dome support rollers (6 total) have a stainless steel rim over a phenolic sleeve to minimize vibration. The eccentrically mounted lock down rollers (6 total) are rubber covered to prevent damage to support track surface during periods of stowage. The rollers (6 total) beneath the track to permit overturning are stainless steel.

3.1.3.2:
The main dome door has three pairs (one roller on each side at top, middle and bottom) of rollers which are on an eccentric arm. Each pair (such as top pair) is operated from a centrally locally square stub shaft. Hand cranks are provided for locking and unlocking the door. Similar eccentric locks are provided for the piggy back door. Pad locks are to be added to the piggy back door to prevent entry of unauthorized personnel. The door in the base has a tumbler type lock.

3.1.3.3:
An oil reservoir type seal is provided between the rotating dome and base. Vin Con C-50 (Conneaut Rubber & Plastics Co.) is used as the seal for the base door, main dome door, piggy back door and between the piggy back and main dome doors. There are no sliding seals. In addition a rubber flap is provided above the seal on the upper end of the main dome door. A shield is extended on each side of the main dome door. A water deflector is attached to the bottom of the main dome door to prevent direct water spray hitting the seal between the main and piggy back doors. A flange is provided above the base door to prevent direct water spray hitting the seal. These flanges, flaps, etc. will decrease the possibilities of water leakage. Vin Con C-50 is satisfactory (see par. 4.2.3).

3.1.4:
The motor drive requirements of this paragraph have been fulfilled.

3.1.4.1:
The drive performance will be covered in test data on each astrodome.

3.1.4.2:
The requirements of this paragraph have been fulfilled except for drive shock mounting. The design is the same as that which was approved by RCA Units 8850 and 8820. The vibration produced by the astrodome did not appear to be excessive. Vibration measuring equipment was not available. The Technical Exhibit does not set levels of allowable vibrations. The Technical Represenative feels that the vibration is not excessive. The drive is acceptable "as-is".

3.1.5:
The initial design approval included provisions for a door in the base which eliminated the requirement for steps.

3.1.6:
The dome is a sandwich type construction using fiberglass and Dow styrofoam #33 (approximately 3" thick). The K factor is .23 to .28 at 40°F. The doors have two inches of Owens Corning Aerocor fiberglass with a K factor of .285 at 75°F.

The door construction is made up in the following order: aluminum skin, one sheet of Alumifoil, 2" fiberglass, one sheet of Alumifoil, aluminum skin.

The base section of dome #2 and 3 and subsequent domes have and will have 3" of fiberglass. #1 dome base has 2" of fiberglass. The Annex will have at least 1" of fiberglass on all surfaces and 2" of fiberglass wherever possible. These insulation provisions are acceptable.

3.1.7:
Three recessed wall lights and one reelite are furnished and are acceptable.

3.2, 3.2.1, 3.2.2, 3.2.2.1:
Quality Control personnel would normally make an inspection on requirements in these paragraphs. There were no Quality Control inspectors present. The Technical Representative reviewed materials used and practices followed. The contractor has taken precautions to furnish a product which will withstand a tropical seashore locale with an absolute minimum of maintenance (see note under drive chain and sprocket problem encountered). It is the opinion of the Technical Respresentative that these requirements were adequately fulfilled.

3.2.2.2:
The contractor used electrical materials which are non-nutrient to fungus. Glass covered wire was used for the motor control. This is acceptable.

3.2.2.3:
Lubrication provided is satisfactory.

3.2.3.1:
The contractor has exercised great care and precautions to minimize dome rolling friction, avoid binds and high spots.

3.3.3.3.1:
These requirements are fulfilled.

3.5:
The contractor has provided a product which indicates good workmanship. The appearance of #1 astrodome is not as good as subsequent astrodomes. Many techniques were perfected and problems solved on #1. This difference in appearance is acceptable.

4.2.1, 4.2.2:
These requirements were fulfilled.

4.2.3:
The seal leakage test was not conducted because of the quantity of water involved in a five minute test on all seals at a pressure of 50 pounds per square inch. That amount of water would flood the plant. The contractor agreed to conduct this test when loading the domes for shipping. Copies of the test results will be furnished.

4.2.4:
The dome was tracked in one direction, then reversed quickly and was found to be satisfactory. The test equipment available would not simulate initial IGOR tracking rates from a stopped position. See discussion under Lag Tests. In view of the fact that the Brush Recorder was available for only a very limited period of time the Technical Representative and the contractor agreed to run one dome about four hours (alternating direction each hour) at 8.6°/sec. rather than run all domes at 5°/sec. for two hours. The test data will provide results.

REVIEW OF REQUIREMENTS OF APPENDICES

Appendix A-1
The contractor forwarded a revised parts list to AFMTC on 6 February 1957. This revised list includes items which were changed in recent months. The contractor advised Mr. Tyler that they would prefer to have spare parts procured from Hofmann rather than OTA. Mr. Tyler was to resolve this problem. Mr. Tyler was advised that spare parts are desired at the earliest possible date.

Instruction Book Manuscript
The contractor forwarded this item to AFMTC on 6 February 1957.

Installation Criteria
Complete.

Drawings
The contractor recently requested a deviation from the drawing requirements. A recommendation of acceptance of their proposal has been made.

The following problems were encountered during inspection and test. Corrective action is indicated.

All Astrodomes

(a) No locks for dome doors to avoid entry of unauthorized personnel -- corrective action: add padlocks to piggy back door.

(b) No serial numbers on astrodomes or thyratron control units -- corrective action: add serial numbers.

(c) The plastic cover over the convenience outlets does not permit proper engagement of male plugs -- corrective action: use metal cover or rearrange attaching devices.

(d) The piggy back door corner strikes the aperture seal when closing the piggy back door and will, in time, damage the seal -- corrective action: install two metal strips on bottom side (one on each end) of main dome door to prevent the corner of the piggy back door touching the seal.

(e) The dome drive sprocket jumps out of engagement with the drive chain with sudden reversal of dome drive. Every fourth chain link is supported with a K-1 attachment. The K-1 holds the chain away from the dome skirt by approximately 3/8".

There were no provisions to hold the links between K-1 attachments on the same radius as the link attached to the K-1. The sprocket jumped at this intermediate point -- corrective action: add two support spacers between each two K-1 attachments. Aluminum spacers were used and are to be treated to prevent galvanic action.

(f) The one dome door lock crank universal joint is welded to prevent swivel action -- corrective action: leave unwelded on others and break weld on the one already made.

Astrodome #1

(a) Lower aperture seal does not fit properly -- corrective action: seal replaced.

(b) Piggy back door rollers do not engage slot in door track -- corrective action: reposition limit stops.

(c) Dome door drive shaft bent -- corrective action: straighten shaft.

(d) Roller which limits drive sprocket engagement in chain hit K-1 attachments -- corrective action: cut radius on corner of roller.

Astrodome #2

(a) Lower main dome door lock decal backwards -- corrective action: reverse decal.

(b) Same as (b) dome #1.

(c) Light switch upside down -- corrective action: reverse switch.

(d) Same as (c) dome #1.

(e) Synchro transformer drive link set screw missing -- corrective action: put in and tighten set screw.

Astrodome #3

(a) Middle main dome door lock decal backwards -- corrective action: reverse decal.

(b) Same as (a) dome #2.

(c) Piggy back door eccentric rollers out of phase or alignment -- corrective action: realign eccentrics.

DESCRIPTION OF TEST EQUIPMENT & TESTS FOR ACCELERATION AND VELOCITY, LAG, ETC.

Test Equipment

(a) Astrodome Evaluator:- A Doelcam 23CX6 transmitter synchro and spotlight projector turntable are driven by a synchronous motor through interchangeable gears and gear reducers. This synchro, when electrically connected with the synchro transformer on the dome drive, provides signals for the dome control unit. The spot of light from the projector is displayed on a target which is on the inner circumference of the rotating portion of the astrodome. The target is graduated in 1/2 and 1 degree increments to 16^{o} clockwise and counter clockwise from a zero center position. The output speed selection available runs from approximately $.2^{o}$/sec. to 20^{o}/sec.

(b) Brush Recorder:- A two channel Brush recorder was used for acceleration data. One synchro transformer rotor lead was connected to one channel. The second channel was connected to the plate switch of the thyratron control panel to indicate zero time. A diagram of the circuit used is available in Optics Engineering.

(c) Stop Watches:-

(d) Spring Scale:-

Test Procedures

(a) Acceleration Data:- Pre and post test calibrations were recorded in CW and CCW directions. The astrodome evaluator synchro was aligned with the dome synchro to obtain zero signal. A two degree error was set in with the evaluator. The amplitude of Brush recorder channel 1 represented a two degree signal. This procedure was followed for CW and CCW signals of 2, 4, 6, 8, 10, 12 and 16 degrees.

After the pre test calibration the synchros were nulled. An eight degree step signal was set in with the evaluator when the dome control unit plate switch was off. The switch was turned on, giving zero time indication and starting the dome drive. Contractor personnel reported that the 60 cycle power frequency is quite stable and the 60 cycles were used for a time base. The channel 1 amplitude and time are compared with the calibration to determine acceleration. This procedure was followed for CW and CCW step signals of 8 and 16 degrees. Three runs were made in each direction.

Acceleration was calculated from $S = 1/2\ AT^2$.

S = degrees travelled
A = acceleration in degrees per second per second
T = time to travel S degrees

(b) Velocity Data:- Three tests were conducted to obtain velocity data. After the synchro is nulled an error signal greater than

6° was set in and held throughout the test. This error signal was started simultaneously with a stop watch. The first test represents average velocity from 0° to 360° or one revolution. The second test is the velocity for one revolution after the dome was at a maximum velocity. The third test is the velocity for two revolutions after the dome was at a maximum velocity.

(c) Lag Tests:- The dome lag was observed from the spot of light described above and taken from Brush Recorder records. An 8.6°/sec. rate was provided by the evaluator. The lag observed exceeds the permissible limits of 4.5° but are attributed to the acceleration of the evaluator. A calibration of the evaluator indicated that it reaches maximum velocity in a fraction of a second (.1 to .2) which surpasses to a great extent the acceleration capabilities of the IGOR instrument. The azimuth rotating mass of IGOR is estimated at approximately four tons. After this initial lag which exceeded the allowable 4.5°, the lag observed was within specification limits. A device to simulate IGOR acceleration (par. 4.2.4 of T.E.) was not available.

(d) Oscillation Test:- Par. 3.1.4.1 of T.E. SE/862-571B states "no serious oscillatory or unstable conditions shall be apparent in the drive system". The oscillations were visually observed by the spot of light on the target described above and taken from Brush Recorder records.

(e) Wind Load Test:- The Technical Exhibit does not specify that the astrodome must track under any wind loading. These tests were conducted for information only and not specifically as an acceptance criterion. A spring scale was held on the dome door track which is at an 8.75' radius from dome center. The load was applied by holding the load fairly uniformly with tracking rates.

<u>Acceleration Data</u>
<u>Paragraph 3.1.4.1</u> of T.E. SE/862-571B - "The IGOR shelter shall be capable of accelerating at ten (10) degrees per second per second".

Test #1 was conducted on Dome #1 on 2/14/57. On 2/15/57 Dome #1 was operated for five hours at 8.6°/second velocity (direction of rotation was reversed each hour) to observe possible degradation of performance after this extended run. This extended run was conducted on #1 and waived on domes #2 and #3. Test #2 was conducted on #1 immediately after the five hour test.

Test #3 was conducted on dome #2 on 2/14/57. The azimuth oil seal was filled with SAE #140 oil to determine possible degradation of performance because of heavier oil. After these tests, the blocks were placed under the drive chain to prevent drive sprocket slippage. Test #4 was conducted on dome #2 on 2/15/57.

Test #5 was conducted on dome #3 on 2/15/57.

NOTES: (1) Tests 2, 4, and 5 were conducted with the astrodomes operating as fieldworthy units with known deficiencies corrected.

(2) Data on the five series of tests described above are Attachment #1 (4 pages).

Velocity Data

Par. 3.1.4.1 of T.E. SE/862-571B - "The maximum tracking rate of the IGOR shelter shall be ten (10) degrees per second."

Dome #1	CW Time	Velocity	CCW Time	Velocity
Test #1 - 0 to 360°	18.5 sec.	19.45° sec.	18.0 sec.	20° sec.
Test #2 - 360° rotation after reaching top speed	15.4 sec.	23.4° sec.	15.4 sec.	23.4° sec.
Test #3 - 720° rotation after reaching top speed	32.0 sec.	22.5° sec.	28.7 sec.	25.1° sec.

Dome #2				
Test #1 - 0° to 360°	15 sec.	24° sec.	14.5 sec.	24.8° sec.
Test #2 - 360° rotation after reaching top speed	13.5 sec	26.6° sec.	12.0 sec.	30° sec.
Test #3 - 720° rotation after reaching top speed	27.0 sec.	26.6° sec.	24.4 sec.	29.5° sec.

Dome #3				
Test #1 - 0° - 360°	16.2 sec.	22.1° sec.	16.2 sec.	22.1° sec.
Test #2 - 360° rotation after reaching top speed	13.3 sec.	27.1° sec.	12.0 sec.	30° sec.
Test #3 - 720° rotation after reaching top speed	27.8 sec.	25.9° sec.	24.0 sec.	30° sec.

 2/25/57

Lag & Oscillation Tests

Dome #1
The astrodome evaluator set in a rate of 8.6°/sec., the dome was operated from 0 to 360° CW.

> 4.5° lag occurred at 1.4 sec. and stopped at 2.68 sec. (duration 1.28 sec.)
> Total Oscillations - 14
> Time for 360° - 44 sec.
> Overshoots - 2

Dome #2
The astrodome evaluator set in a rate of .88°/sec., the dome was operated from 0 to 30° CW, then 0 to 30° CCW.

	C.W.	C.C.W.
First Lag	[illegible].4°	2°
Maximum Lag	1.6°	2.7°
Oscillations	6	5½
~~Travel Time~~' from 0-30°	34.5 sec.	34.5 sec.

The astrodome evaluator set in a rate of 8.6°/sec., the dome was operated from 0 to 360° CW.

> [illegible]° lag occurred at .533 sec. and stopped at 1.766 sec. (duration 1.233 sec.)
> Total Oscillations - 11
> Time for 360° - 42 sec.
> Overshoots - 2

The astrodome evaluator set in a rate of 12.7°/sec., the dome was operated 0 to 360° CCW.

> 4.5° lag occurred at .65 sec. and stopped at 3.016 sec. (duration 2.336sec.)
> Total Oscillations - 10
> Time for 360° - 28.4 sec.
> Overshoots - 3

Dome #3
The astrodome evaluator set in a rate of 8.6°/sec., the dome was operated from 0 to 180° CW.

> 4.5° lag occurred at 1.316 sec. and stopped at 2.45 sec. (duration 1.134 sec.)
> Total Oscillations in 180° - 6½
> Time for 180° - 21.8 sec.
> Overshoots - 1

Exhibit II

The astrodome evaluator set in a rate of 8.6°/sec., the dome was operated from 0 to 180° CCW.

> 4.5° lag occurred at .98 sec. and stopped at 1.6 sec.
> (duration .62 sec.)
> Total Oscillations in 180° - ---
> Time for 180° - 21.3 sec.
> Overshoots - 1

<u>Wind Load Tests</u>
Preliminary tests revealed that all three domes performed similarly under various loadings at different velocities. Typical data were recorded from astrodome #3.

The evaluator put in a rate of .2 and 8.6° sec.

Rate	Direction	Load Applied	Lag Range
.2	CW	20 lbs.	2½°-3°
.2	CCW	20 lbs.	2½°-3°
.2	CW	40 lbs.	2½°-3½°
.2	CCW	40 lbs.	2½°-3½°
.2	CW	50 lbs.	3°-3½°
.2	CCW	50 lbs.	3°-3½°
.2	CW	80 lbs.	2½°-3½°
.2	CCW	80 lbs.	2½°-3½°
8.6	CW	30 lbs.	2½°-4°
8.6	CCW	30 lbs.	2½°-4°
8.6	CW	50 lbs.	3°-6°
8.6	CCW	50 lbs.	3°-6°

<u>Conclusions:</u>
Astrodomes #1, 2 and 3 are acceptable when changes discussed herein are completed and upon satisfactory results of seal leakage tests. Astrodome drive control units #2 and 3 are acceptable. Astrodome drive control unit #1 must be checked by the contractor to determine reason for low CCW acceleration, corrective action taken, and unit shipped to AFMTC.

<u>Recommendation:</u>
It is recommended that the ACO take action as indicated in conclusions above. The #1 control unit may be shipped separately within three weeks of astrodome shipment. Astrodomes #1, 2 and 3 are to be shipped together.

G. B. Cope
Technical Representative

gbc/rt

Exhibit II

Astrodome #1 Acceleration Test

Test #2

ATTACHMENT #1

/25/57

(Calibration Data is available In Option Group)

#1 Step Signal in Degrees	Run I CW Time in Seconds	Run I CW Acceleration °/sec/sec	Run II CW Time in Seconds	Run II CW Acceleration °/sec/sec	Run III CW Time in Seconds	Run III CW Acceleration °/sec/sec	Run I CCW Time in Seconds	Run I CCW Acceleration °/sec/sec	Run II CCW Time in Seconds	Run II CCW Acceleration °/sec/sec	Run III CCW Time in Seconds	Run III CCW Acceleration °/sec/sec
16	0		0		0		0		0		0	
12	.716	15.5	.728	15.5	.683	17.15	.75	19.25	.716	15.5	No Test	
10	.916	14.28	.916	14.28	.916	14.28	.95	13.3	.933	13.7		
8	1.116	12.88	1.1	13.22	1.08	13.57	1.11	12.9	1.15	12.1		
6	1.25	12.8	1.25	12.3	1.28	12.2	1.23	13.2	1.3	11.9		
4	1.4	12.25	1.4	11.64	1.4	12.2	1.41	12.0	1.45	11.4		
2	1.55	11.68	1.58	11.2	1.5	11.3	1.55	11.6	1.6	10.9		
0	1.73	10.66	1.76	10.25	1.7	10.6	1.72	10.2	1.8	9.8		
8	0											
6	.55	13.2	.533	14.07	.5	16.	.5	16.0	.483	17.2	.466	18.3
4	.8	12.5	.75	14.1	.76	13.6	.733	14.87	.733	14.87	.716	15.5
2	1.1	9.92	.98	12.4	.95	13.3	.95	13.3	1.016	11.55	.916	14.3
0	1.3	9.53	1.3	9.54	1.23	10.5	1.20	11.1	1.35	9.75	1.216	10.8

Test #2

Calibration Data (Pre Test) *

Step Signal in Degrees	Brush Recorder Amplitude in Divisions CW	CCW
0	0	0
2	2	2
4	4	4
6	7	7
8	9	9.5
10	11.5	11.5
12	13.5	13.5
16	18	18

NOTE: The ink ran on the post calibration data making it unusable.

Best Available Copy

ATTACHMENT #1
2/25/57

Exhibit II

[illegible] #2 Acceleration Test
Test #2 Continued

Step Signal in Degrees	Run I CW Time in Seconds	Run I CW Accel. °/sec/sec	Run II CW Time in Seconds	Run II CW Accel. °/sec/sec	Run III CW Time in Seconds	Run III CW Accel. °/sec/sec	Run I CCW Time in Seconds	Run I CCW Accel. °/sec/sec	Run II CCW Time in Seconds	Run II CCW Accel. °/sec/sec	Run III CCW Time in Seconds	Run III CCW Accel. °/sec/sec
16	0		0		0		0		0		0	
12	.8	12.5	.8	12.5	.75	14.2	1.0	8.0	.95	[illegible]	[illegible]	[illegible]
10	1.0	12.0	.95	13.3	.95	13.3	1.25	7.7	1.15	9.1	1.25	[illegible]
8	1.15	12.1	1.15	12.1	1.15	12.1	1.45	7.62	1.3	9.5	1.45	[illegible]
6	1.3	11.9	1.25	12.8	1.3	11.9	1.65	7.35	1.55	8.3	1.65	[illegible]
4	1.45	11.4	1.45	11.4	1.475	11.0	1.85	7.0	1.8	7.4	1.85	[illegible]
2	1.6	10.9	1.55	11.6	1.6	10.9	2.0	7.0	1.9	[illegible]	2.0	7.0
0												
8	0		0		0		0		0		0	
6	.5	16.	.5	16.	.4	25.	.6	11.1	.6	11.1	.6	[illegible]
4	.8	12.5	.8	12.5	.8	12.5	1.0	8.	1.0	8.	1.0	8.
2	1.0	12.	.975	12.6	.975	12.6	1.2	[illegible]	1.275	7.8	1.275	7.8
0												

Attachment [illegible] Test #3

(Calibration data on file in Optics Group)

Step Signal in Degrees	Run I CW Time in Seconds	Run I CW Accel. °/sec/sec	Run II CW Time in Seconds	Run II CW Accel. °/sec/sec	Run III CW Time in Seconds	Run III CW Accel. °/sec/sec	Run I CCW Time in Seconds	Run I CCW Accel. °/sec/sec	Run II CCW Time in Seconds	Run II CCW Accel. °/sec/sec	Run III CCW Time in Seconds	Run III CCW Accel. °/sec/sec
16	0		0		0		0		0		0	
12	.75	14.21	.81	12.2	.835	11.48	.75	14.21	[illegible]	[illegible]	.8	[illegible]
10	1.01	11.75	1.04	11.1	1.05	10.86	1.03	11.3	[illegible]	9.1	1.16	[illegible]
8	1.18	11.5	1.23	10.6	1.25	10.25	1.25	10.25	1.26	[illegible]	[illegible]	[illegible]
6	1.375	10.6	1.43	9.79	1.44	9.66	[illegible]	10.2	1.45	[illegible]	[illegible]	[illegible]
4	1.5	10.6	1.58	9.63	1.60	9.38	1.6	9.45	1.63	[illegible]	[illegible]	[illegible]
2			1.73	9.37	1.74	9.25	1.75	9.35	1.75	[illegible]	[illegible]	[illegible]
0												
8	0		0		0		0		0		0	
6	.566	12.5	.583	11.75	.55	13.22	.47	[illegible]	[illegible]	[illegible]	.514	[illegible]
4	.883	10.25	.866	10.66	.82	11.9	.77	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	1.1	9.68	1.066	10.58	1.058	10.7	[illegible]	[illegible]	1.01	[illegible]	[illegible]	[illegible]
0	1.3	9.46	1.28	9.75	1.26	10.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Calibration Data (Pre Test) Test #4

Step Signal in degrees	Brush Recorder Amplitude in Divisions CW	CCW	Post CW	Post CCW	Average CW	Average CCW
0						
2	2	2	2	2	2	2
4	4	4	4	4	4	4
6	6.5	7	7	7	7	7
8	9	9	9	9	9	9
10	11.5	11.5	11.5	11.5	11.5	11.5
12	13.5	13.5	13.5	13.5	13.5	13.5
16	17.5	17.5	17.5	17.5	17.5	17.5

Step Signal in degrees	Run I CW Time in Seconds	Run I CW Accel. °/sec/sec	Run II CW Time in Seconds	Run II CW Accel. °/sec/sec	Run III CW Time in Seconds	Run III CW Accel. °/sec/sec	Run I CCW Time in Seconds	Run I CCW Accel. °/sec/sec	Run II CCW Time in Seconds	Run II CCW Accel. °/sec/sec	Run III CCW Time in Seconds	Run III CCW Accel. °/sec/sec
16	0		0		0		0		0		0	
12	.75	14.25	.7	16.3	.65	19.0	.8	12.5	.8	12.5	.8	12.5
10	.95	13.3	.85	16.7	.9	14.8	1.0	12.0	.95	13.3	1.0	12.0
8	1.1	13.2	1.1	13.2	1.05	14.55	1.2	11.1	1.15	13.2	1.15	13.2
6	1.25	12.8	1.2	13.9	1.15	15.15	1.3	[illegible]	1.25	12.8	1.3	11.9
4	1.35	13.2	1.35	13.2	1.35	13.2	1.45	11.4	1.45	11.4	1.45	11.4
2	1.5	12.5	1.5	12.5	1.45	13.3	1.6	10.9	1.55	11.6	1.55	11.6
0												
8	0		0		0		0		0		0	
6	.5	16.	.5	16.	.5	16.	.45	19.8	.5	16.0	.55	13.25
4	.85	11.05	.8	12.5	.75	14.2	.75	14.2	.8	12.5	.8	12.5
2	1.0	12.	1.0	12.	.9	14.8	.95	13.3	.95	13.3	.95	13.3
0												

Astrodome # Test #5

Calibration Data Pre Test

Step Signal in degrees	Brush Recorder Amplitude in Div. CW	CCW	Post CW	Post CCW	Average CW	Average CCW
0						
2	2.1	2.8	2.1	2.1	2.1	2.5
4	4.2	4.1	4.1	4.5	4.2	4.3
6	7	7	6.9	7	7	7
8	8.5	9	9	9	9	9
10	11.4	11.5	11.6	11.6	11.5	11.6
12	14	13.9	13.5	13.9	14	14
15	17.1	17	17.1	17	17.1	17

Exhibit II

Astrodome 8 Acceleration Test
Test #5 Continued

ATTACHMENT #1
[illegible]/25/57

Step Signal in degrees	Run I CW Time in Seconds	Run I CW Accel. °/sec/sec	Run II CW Time in Seconds	Run II CW Accel. °/sec/sec	Run III CW Time in Seconds	Run III CW Accel. °/sec/sec	Run I CCW Time in Seconds	Run I CCW Accel. °/sec/sec	Run II CCW Time in Seconds	Run II CCW Accel. °/sec/sec	Run III CCW Time in Seconds	Run III CCW Accel. °/sec/sec
16	0		0		0		0		0		0	
12	.85	11.1	.75	14.2	.75	14.2	.72	15.4	.85	11.1	.67	17.8
10	1.05	10.9	.95	13.3	1.0	12.0	.9	14.8	1.1	9.83	.9	14.8
8	1.35	8.8	1.10	13.2	1.15	12.1	1.13	12.5	1.33	9.1	1.12	12.7
6	1.50	8.95	1.30	11.9	1.25	12.8	1.27	12.2	1.6	7.82	1.22	13.5
4	1.65	8.83	1.45	11.4	1.40	12.2	1.48	10.9	1.72	8.1	1.38	13.3
2	1.80		1.50		1.6		1.58		1.85		1.48	
8	0		0		0		0		0		0	
6	.5	16	.7	8.33	.5	16	.52	15.4	.55	13.25	.53	14.2
4	.8	12.5	1.03	7.55	.8	12.5	.82	12.1	.8	12.5	.9	9.87
2	1.0	12.0	1.14	9.25	1.0	12.0	.95	13.3	1.02	11.5	1.05	10.9
0												

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Exhibit III

MEMORANDUM FOR THE RECORD

25 March 1957
W.A. 02-62016

SUBJECT: IGOR Astrodome Tests Contract AF08(606)-1212

The Alfred Hofmann Company, Murfreesboro, Tennessee, conducted water spray tests on No. 1, 2 and 3 IGOR Astrodomes. The following report which was certified by a Notary Public was submitted to the Technical Representative:

"This will certify that on March 5, 1957 and March 8, 1957 Igor Domes #1001, 1002 and 1003 were subjected to water test as follows:

All doors were locked shut and stream of water from hose nozzle was played on dome from different angles directly on seals for a period of fifteen minutes.

Results: No leaks were observed around any of the door seals.

The water pressure at nozzle was cut down to give maximum pressure. Pumps delivering water set on 60 lbs.

Dome #1001 was tested March 8, 1957.

Domes #1002 and 1003 were tested March 5, 1957."

The No. 1 Dome control unit was inspected. The following information describes condition found and action taken:

a. Biases as found when unit first turned on:
   Zero: S2 1.2 volts positive with respect to S1
   DC Bias: K1 32 volts positive with respect to G1
   K2 25.5 volts positive with respect to G2
   AC Bias: S1 21 volts rms. to G1
   S2 20 volts rms. to G2

b. Replaced V4 with new 6SN7 and put in two new thyratrons EL 710/6011.

c. Final Bias Adjustments:
   Zero: Set dc voltage between S1 and S2 to zero
   AC Bias: S1 19 volts rms. to G1
   S2 19 volts rms. to G2
   DC Bias: K1 25 volts positive with respect to G1
   K2 25 volts positive with respect to G2

These actions conclude final tests on Astrodomes No. 1, 2 and 3 and all now acceptable.

G. B. Cope

G. B. Cope
Technical Representative

EXHIBIT IV

Attachment No. 1 27 June 1957

VELOCITY DATA

Dome No. 4:

	CW Time	Velocity	CCW Time	Velocity
Test No. 1 0 to 360°	14.0 sec.	25.7°/sec.	14.5 sec.	24.8°/sec.
Test No. 2 0 to 720°	24.5 sec.	29.4°/sec.	25.5 sec.	28.2°/sec.
Test No. 3 720° rotation after reaching top speed	20.5 sec.	35.2°/sec.	20.9 sec.	34.4°/sec.

Dome No. 5:

	CW Time	Velocity	CCW Time	Velocity
Test No. 1 0 to 360°	14.9 sec.	24.2°/sec.	14.0 sec.	25.7°/sec.
Test No. 2 0 to 720°	25.3 sec.	28.4°/sec.	24.0 sec.	30°/sec.
Test No. 3 720° rotation after reaching top speed	20.6 sec.	35°/sec.	20.0 sec.	36°/sec.

Dome No. 6:

	CW Time	Velocity	CCW Time	Velocity
Test No. 1 0 to 360°	14.0 sec.	25.7°/sec.	14.5 sec.	24.8°/sec.
Test No. 2 0 to 720°	24.5 sec.	29.4°/sec.	25.3 sec.	28.4°/sec.
Test No. 3 720° rotation after reaching top speed	21.2 sec.	33.9°/sec.	22.0 sec.	32.7°/sec.

Attachment No. 2 27 June 1957

LAG, OSCILLATION AND OVERSHOOT TESTS

Demo No. 4:

0.38°/sec velocity, 30° rotation

	CW	CCW
Maximum Lag	1-1/4°	1-1/3°
Total Oscillations	15	12
Time for 30° rotation	79 sec.	79 sec.
Overshoots	3	2

8.6°/sec velocity, 360° rotation

	CW	CCW
Maximum Lag	6-1/2° (exceeded 4.5° for 3-1/2 sec.)	5-1/2° (exceeded 4.5° for 2-1/2 sec.)
Total Oscillations	8	9
Time for 360° rotation	41.8 sec.	41.8 sec.
Overshoots	3	2

Demo No. 5:

0.38°/sec velocity, 30° rotation

	Before Heat Run		After Heat Run	
	CW	CCW	CW	CCW
Maximum Lag	1-1/3°	1-1/3°	1-1/4°	1-1/5°
Total Oscillations	15	14	13	15
Time for 30° rotation	79 sec.	79 sec.	79 sec.	79 sec.
Overshoots	1	1	2	1

8.6°/sec velocity, 360° rotation

	Before Heat Run		After Heat Run	
	CW	CCW	CW	CCW
Maximum Lag	6°	5-1/2°	6°	5-1/2°
Time lag exceeded 4.5°	7-1/2 sec.	6-1/2 sec.	4 sec.	4 sec.
Total Oscillations	12	11	8	9
Time for 360° rotation	41.8 sec.	41.8 sec.	41.8 sec.	41.8 sec.
Overshoots	[illegible]	3	3	[illegible]

LAG, OSCILLATION AND OVERSHOOT TESTS (Cont)

Dome No. 6:

0.38°/sec velocity, 30° rotation

	CW	CCW
Maximum Lag	1-1/5°	1-1/6°
Total Oscillations	12	13
Time for 30° rotation	79 sec.	79 sec.
Overshoots	2	2

8.6°/sec velocity, 360° rotation

	CW	CCW
Maximum Lag	8°	6°
Time Lag exceeded 4.5°	5-1/2 sec.	3 sec.
Total Oscillations	10	13
Time for 360° rotation	41.8 sec.	41.8 sec.
Overshoots	3	3

Attachment No. 3 27 June 1957

WIND LOAD TESTS

With the Astrodomes operating at a velocity of 8.6°/sec., the following loads were applied at 8.75' radius and lags encountered are noted:

	Dome No. 4	Dome No. 5	Dome No. 6
30 lbs. CW	2-1/2 - 3-1/2°	2 - 3°	2 - 3°
30 lbs. CCW	2-1/2 - 3-1/2°	2 - 3°	3 - 4°
50 lbs. CW	3 - 4°	4 - 4-1/2°	4 - 5°
50 lbs. CCW	3-1/2 - 4-1/2°	4 - 4-1/2°	4 - 4-1/2°

Attachment No. 4

[illegible]

[illegible]

	Step Signal in Degrees	Pre Test CW	Pre Test CCW	Post Test CW	Post Test CCW	[illegible] CW	[illegible] CCW
Dome No. 4	2.6	3	2.5	3	2.5	3	2.5
	5.2	6	6	6.5	6	6	6
	7.8	9.5	9.5	10	9.5	10	9.5
	10.4	13	13	13	12.5	13	13
	13.0	16	16	16	15.5	16	16
	15.6	18	18	18	18	18	18
	20.8	22	22	22	22	22	22
Dome No. 5 (Before Heat Run)	2.6	2	2	2	2	2	2
	5.2	6	6	6	6	6	6
	7.8	9	9	9	9	9	9
	10.4	12	12	12	13	12	12.5
	13.0	15	15	15	15	13	15
	15.6	18	18	18	18	18	18
	20.8	22	22	22	22	22	22
Dome No. 5 (After Heat Run)	2.6	3	3	2	3	2.5	3
	5.2	6	6	6	6	6	6
	7.8	9.5	10	9.5	10	9.5	10
	10.4	13	13	13	13	13	13
	13.0	16	16	15.5	16	16	16
	15.6	18	18	18	18	18	18
	20.8	22	22	22	22	22	22
Dome No. 6	2.6	3	3	No Post Test Calibration			
	5.2	6	6				
	7.8	10	10				
	10.4	12	12				
	13.0	15	15				
	15.6	18	18				
	20.8	21	21				

ACCELERATION DATA

NOTE: All time in seconds and acceleration in degrees/second/second

Dome	Test	Step Signal in Degrees	TIME	ACCLER	TIME	ACCLER	TIME	ACCLER
			Run I	CW	Run II	CW	Run III	CW
No. 4	No. 1	2.6	1.316	8.97	1.264	9.76	1.316	8.97
		5.2	.880	13.39	.980	10.8	.980	10.8
		7.8	.464	12.02	.580	15.45	.580	15.45
		10.4	0		0		0	
			Run I	CCW	Run II	CCW	Run III	CCW
		2.6	1.232	10.25	1.232	10.25	1.316	8.97
		5.2	.964	11.2	.980	10.8	1.032	9.75
		7.8	.648	12.4	.648	12.4	.648	12.4
		10.4	0		0		0	
			Run I	CW	Run II	CW	Run III	CW
	No. 2	2.6	1.[illegible]	9.25	2.10	8.33	2.[illegible]	[illegible]
		5.2	1.80	9.68	1.90	8.67	1.692	9.25
		7.8	1.632	9.76	1.68	9.22	1.632	9.76
		10.4	1.432	10.1	1.48	9.47	1.492	[illegible]
		13.0	1.216	10.53	1.238	10.23	1.20	10.[illegible]
		15.6	.964	11.18	1.10	8.98	.964	11.18
		20.8	0		0		0	
			Run I	CCW	Run II	CCW	Run III	CCW
		2.6	2.132	7.97	2.10	8.33	2.1[illegible]	7.[illegible]
		5.2	1.948	8.22	1.916	8.53	2.00	7.8
		7.8	1.748	8.52	1.716	8.83	1.80	8.68
		10.4	1.532	8.90	1.464	9.72	1.532	8.9
		13.0	1.220	11.18	1.232	10.23	1.30	9.23
		15.6	1.064	9.16	1.016	10.03	1.064	10.[illegible]
		20.8	0		0		0	

ACCELERATION DATA
(Cont)

Pump	Test	Step Signal in Degrees	TIME	ACCL'N	TIME	ACCL'N	TIME	ACCL'N
			Run I	CW	Run II	CW	Run III	CW
No.5	No.1 (Before Heat Run)	2.6	1.316	9.08	1.380	8.21	1.316	9.08
		5.2	1.048	9.45	1.064	9.15	1.048	9.45
		7.8	.748	9.28	.780	8.55	.748	9.28
		10.4	0		0		0	
			Run I	CCW	Run II	CCW	Run III	CCW
		2.6	1.316	9.08	1.348	8.61	1.316	9.08
		5.2	1.016	10.0	1.064	9.15	1.016	10.0
		7.8	.748	9.28	.780	8.55	.748	9.28
		10.4	0		0		0	
			Run I	CW	Run II	CW	Run III	CW
	No.2 (Before Heat Run)	2.6	2.116	8.66	2.064	8.5	2.216	7.04
		5.2	1.932	8.35	1.900	8.66	2.00	7.8
		7.8	1.732	8.68	1.748	8.5	1.832	7.74
		10.4	1.580	8.33	1.580	8.33	1.648	7.7
		13.0	1.316	9.18	1.316	9.18	1.348	8.67
		15.6	1.016	10.0	1.048	9.63	1.00	10.4
		20.8	0		0		0	
			Run I	CCW	Run II	CCW	Run III	CCW
		2.6	2.380	6.41	2.364	6.50	2.180	7.65
		5.2	2.180	6.55	2.180	6.55	2.032	7.56
		7.8	1.948	6.85	1.964	6.74	1.816	7.88
		10.4	1.716	7.08	1.70	7.17	1.632	7.77
		13.0	1.50	6.96	1.532	6.66	1.448	7.42
		15.6	1.164	7.88	1.164	7.88	1.116	8.38
		20.8	0		0		0	
			Run I	CW	Run II	CW	Run III	CW
	No.1 (After Heat Run)	2.6	1.216	10.52	1.248	10.6	1.164	12.6
		5.2	.964	11.2	.980	10.82	.932	11.9
		7.8	.648	12.38	.700	10.62	.632	13.0
		10.4	0		0		0	
			Run I	CCW	Run II	CCW	Run III	CCW
		2.6	1.188	11.13	1.148	12.78	1.148	12.78
		5.2	.948	11.55	.932	11.9	.916	12.35
		7.8	.548	17.35	.548	17.35	.548	17.35
		10.4	0		0		0	

ACCELERATION DATA
(Cont)

Dose	Test	Step Signal in Degrees	TIME	ACCLRN	TIME	ACCLRN	TIME	ACCLRN
			Run I	CW	Run II	CW	Run III	CW
No.5 (After Heat Run)	No.2	2.6	2.20	7.53	2.064	8.55	2.10	8.[illegible]
		5.2	2.032	7.55	1.880	8.82	1.948	8.[illegible]
		7.8	1.832	7.74	1.70	9.03	1.748	8.56
		10.4	1.60	8.14	1.48	9.45	1 [illegible]32	8.82
		13.0	1.348	8.67	1.248	10.0	1.[illegible]8	9.52
		15.6	1.10	8.6	1.00	10.4	1.08	8.94
		20.8	0		0		0	
			Run I	CCW	Run II	CCW	Run III	CCW
		2.6	2.132	8.01	1.964	9.44	2.064	8.55
		5.2	2.00	7.8	1.816	9.45	1.932	8.35
		7.8	1.664	9.4	1.60	10.15	1.716	8.8
		10.4	1.548	8.71	1.416	10.4	1.516	9.05
		13.0	1.332	8.77	1.180	11.2	1.30	9.23
		15.6	1.116	8.35	.964	11.18	1.064	9.15
		20.8	0		0		0	
No.6	No.1		Run I	CW	Run II	CW	Run III	CW
		2.6	1.132	11.22	1.20	10.82	1.148	11.85
		5.2	.932	11.95	1.00	10.4	.948	11.55
		7.8	.532	18.3	.664	11.7	.564	16.32
		10.4	0		0		0	
			Run I	CCW	Run II	CCW	Run III	CCW
		2.6	1.164	11.48	1.116	12.5	1.116	12.5
		5.2	.980	9.25	.900	12.84	.916	12.38
		7.8	.600	14.42	.532	18.3	.532	18.3
		10.4	0		0		0	
	No.2		Run I	CW	Run II	CW	Run III	CW
		2.6	1.916	9.95	1.916	9.95	1.880	10.28
		5.2	1.80	9.63	1.780	9.86	1.732	10.4
		7.8	1.548	10.82	1.564	10.65	1.516	8.67
		10.4	1.448	9.9	1.448	9.9	1.40	10.62
		13.0	1.232	10.24	1.264	9.75	1.20	10.84
		15.6	.948	11.55	.964	11.2	.916	12.38
		20.8	0		0		0	
			Run I	CCW	Run II	CCW	Run III	CCW
		2.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		5.2	2.20	6.45	1.832	9.20	1.926	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	10.4	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

EXHIBIT V

ACCELERATION DATA

Dome No. 5 - Before Heat Run

[illegible] seconds and acceleration in degrees/second/second.

	Signal Degrees	Run #1 Time	Run #1 Accn.	Run #2 Time	Run #2 Accn.	Run #3 Time	Run #3 Accn.	Run #4 Time	Run #4 Accn.	Run #5 Time	Run #5 Accn.
	16	0		0		0		0		0	
	12	.91	9.7	.9	9.9	.88	10.3	.81	12.2	.82	11.9
	10	1.18	8.6	1.16	8.9	1.11	9.76	1.04	11.1	1.06	10.6
	8	1.44	7.7	1.43	7.8	1.35	8.8	1.25	10.2	1.28	9.8
	6	1.63	7.51	1.52	8.6	1.57	8.13	1.41	10.0	1.44	9.7
	4	1.84	7.1	1.85	7.02	1.78	7.58	1.58	9.6	1.63	9.0
	2	2.0	7.0	1.99	7.08	1.93	7.53	1.7	9.8	1.74	9.25
	0	2.15	6.9	2.14	7.0	2.08	7.4	1.86	9.25	1.93	8.6
[illegible]	16	0		0		0		0		0	
	12	.87	10.5	.76	13.8	.86	10.8	.87	10.5	.84	11.3
	10	1.13	9.4	1.03	11.3	1.09	10.1	1.12	9.6	1.07	10.5
	8	1.37	8.5	1.28	9.75	1.32	9.2	1.36	8.65	1.29	9.6
	6	1.57	8.13	1.47	9.25	1.52	8.67	1.57	8.13	1.48	9.1
	4	1.74	7.92	1.66	8.7	1.72	8.16	1.72	8.1	1.66	8.7
	2	1.92	7.55	1.82	8.45	1.9	7.76	1.89	7.85	1.82	8.45
	0	2.07	7.45	1.96	8.34	2.06	7.56	2.03	7.8	1.96	8.34
CW	8	0		0		0		0		0	
	6	.555	13.0	.55	13.2	.56	12.7	.55	13.2	.56	12.7
	4	.87	10.5	.88	10.3	.89	10.1	.86	10.8	.89	10.1
	2	1.08	10.2	1.11	9.77	1.12	9.6	1.06	10.7	1.11	9.8
	0	1.33	9.1	1.34	8.94	1.35	8.8	1.28	9.7	1.32	9.2
CCW	8	0		0		0		0		0	
	6	.48	17.3	.55	13.2	.58	11.9	.5	15.	.54	13.7
	4	.82	11.9	.87	10.6	.89	10.1	.86	10.8	.87	10.5
	2	1.06	10.7	1.09	10.1	1.12	9.6	1.06	10.7	1.09	10.1
	0	1.26	10.05	1.37	8.6	1.36	8.7	1.28	9.8	1.32	9.2

BEFORE HEAT RUN CALIBRATION

Brush Recorder Amplitude In Divisions

me #5	Error Signal in Degrees	Pre-Test Calibration	Post Test Calibration	Average
CW	2	1.2	1.3	1.3
	4	3.0	3.0	3.0
	6	5.1	5.1	5.1
	8	6.9	7.1	7.0
	10	9.1	9.1	9.1
	12	Assume 10.9 (not taken)	10.9	10.9
	16	14.7	14.7	14.7
CCW	2	1.6	1.5	1.6
	4	3.1	3.2	3.2
	6	5.4	5.1	5.3
	8	7.0	7.2	7.1
	10	9.3	9.1	9.2
	12	11.1	10.9	11.0
	16	14.9	14.8	14.9

AFTER HEAT RUN CALIBRATION

CW	2	1.4	1.3	1.4
	4	3.2	3.2	3.2
	6	5.1	5.1	5.1
	8	7.0	7.1	7.0
	10	9.1	9.1	9.1
	12	11.0	11.1	11.1
	16	14.6	14.6	14.6
CCW	2	1.6	1.6	1.6
	4	3.1	3.3	3.2
	6	5.2	5.4	5.3
	8	7.1	7.2	7.2
	10	9.1	9.1	9.1
	12	11.2	11.1	11.1
	16	14.7	14.8	14.7

ACCELERATION DATA

Dome No. 5 - After Heat Run

Time in seconds and acceleration in degrees/second/second.

	Error Signal in Degrees	Run #6 Time	Run #6 Accn.	Run #7 Time	Run #7 Accn.	Run #8 Time	Run #8 Accn.	Run #9 Time	Run #9 Accn.	Run #10 Time	Run #10 Accn.
	16	0		0		0		0		0	
	12	.82	11.9	.85	11.1	.87	10.6	.84	11.3	.84	11.3
	10	1.01	11.8	1.07	10.4	1.08	10.3	1.08	10.3	1.07	10.4
	8	1.22	10.7	1.28	9.8	1.29	9.6	1.26	10.0	1.28	9.7
	6	1.40	10.2	1.44	9.7	1.45	9.5	1.41	10.0	1.44	9.6
	4	1.54	10.1	1.60	9.4	1.61	9.3	1.57	9.7	1.59	9.5
	2	1.67	10.0	1.72	9.4	1.73	9.4	1.71	9.6	1.76	9.0
	0	1.82	9.6	1.87	9.1	1.89	9.0	1.83	9.5	1.88	9.0
	16	0		0		0		0		0	
	12	.89	10.1	.84	11.4	.86	10.8	.83	11.6	187	10.6
	10	1.12	9.6	1.10	9.9	1.11	9.8	1.08	10.3	1.10	9.9
	8	1.35	8.8	1.31	9.3	1.32	9.2	1.27	9.9	1.29	9.6
	6	1.53	8.5	1.49	9.0	1.53	8.55	1.47	9.3	1.50	8.9
	4	1.72	8.1	1.64	8.9	1.69	8.4	1.62	9.2	1.64	8.9
	2	1.83	8.3	1.80	8.65	1.81	8.5	1.78	8.8	1.82	8.5
	0	2.02	7.8	1.98	8.17	2.0	8.0	1.95	8.4	1.99	8.1
CW	8	0		0		0		0		0	
	6	.58	12.8	.53	14.2	.57	12.3	.56	12.8	.55	13.2
	4	.83	11.6	.79	12.8	.86	10.8	.84	11.3	.84	11.3
	2	1.02	11.5	1.01	11.8	1.06	10.7	1.05	10.9	1.05	10.9
	0	1.20	11.1	1.20	11.1	1.27	9.9	1.23	10.6	1.23	10.6
CCW	8	0		0		0		0		0	
	6	.56	12.8	.57	12.3	.62	10.4	.59	11.5	.58	11.9
	4	.86	10.8	.87	10.6	.93	9.3	.89	10.1	.88	10.3
	2	1.11	9.7	1.12	9.6	1.17	8.8	1.11	9.8	1.09	10.1
	0	1.32	9.2	1.33	9.0	1.37	8.5	1.34	8.9	1.32	9.2

		Run #11 Time	Run #11 Accn.	Run #12 Time	Run #12 Accn.
CCW	8	0		0	
	6	.55	13.2	.57	12.3
	4	.87	10.6	.88	10.3
	2	1.07	10.4	1.09	10.1
	0	1.29	9.6	1.32	9.2

EXHIBIT VI

13 June 1957

The following agreements are hereby entered into by Air Force Missile Test Center and Oerlikon Tool & Arms Corporation.

1. The proposed method of improving the Astrodome oil seals so that they meet the requirements of paragraph 3.1.8.3 of Technical Exhibit SE/862-571B shall be essentially as follows. The device will consist of a rubber sheet of suitable composition to withstand weather conditions at a seashore location and flexing when the seal is opened to the non-seal condition. The rubber sheet will be of sufficient width to come down over the metal skirt around the upper rotating section and to extend in against the lower base section. The sheet will be folded and will enclose in the fold a rubber bungee cord, and the edges will be placed together and held tightly against the aluminum angle at the lower edge of the upper rotating section by means of the metal skirt and screws. In operation, it will be necessary in order to open the seal to pull the rubber sheet and bungee cord out away from the lower base section and up over the metal skirt on the lower edge of the upper rotating section. Suitable means shall be provided to initiate the manual opening of the seal without damage to the seal or dome and a method of preventing the seal from returning to closed position during periods of operation shall be provided. The design shall be essentially as shown in the attached sketch.

2. Oerlikon shall furnish three (3) of the above described rubber seals and shall perform installation of these seals on Astrodomes Nos. 4, 5, and 6.

3. Upon installation of the rubber seals on Astrodomes Nos. 4, 5, and 6, Air Force Missile Test Center will accept these units and the Contractor shall not be liable for any further change or modification to the Dome seal.

	(signed) John L. Nichols
GERHARD A. HENGST	JOHN L. NICHOLS
Directorate of Range	Assistant to President
Development	Oerlikon Tool & Arms. Corp.
	(signed) Herbert W. Huebner
GERALD B. COPE	HERBERT W. HUEBNER
[illegible] Services Co., Inc.	1st Lt., USAF
	Procurement Office

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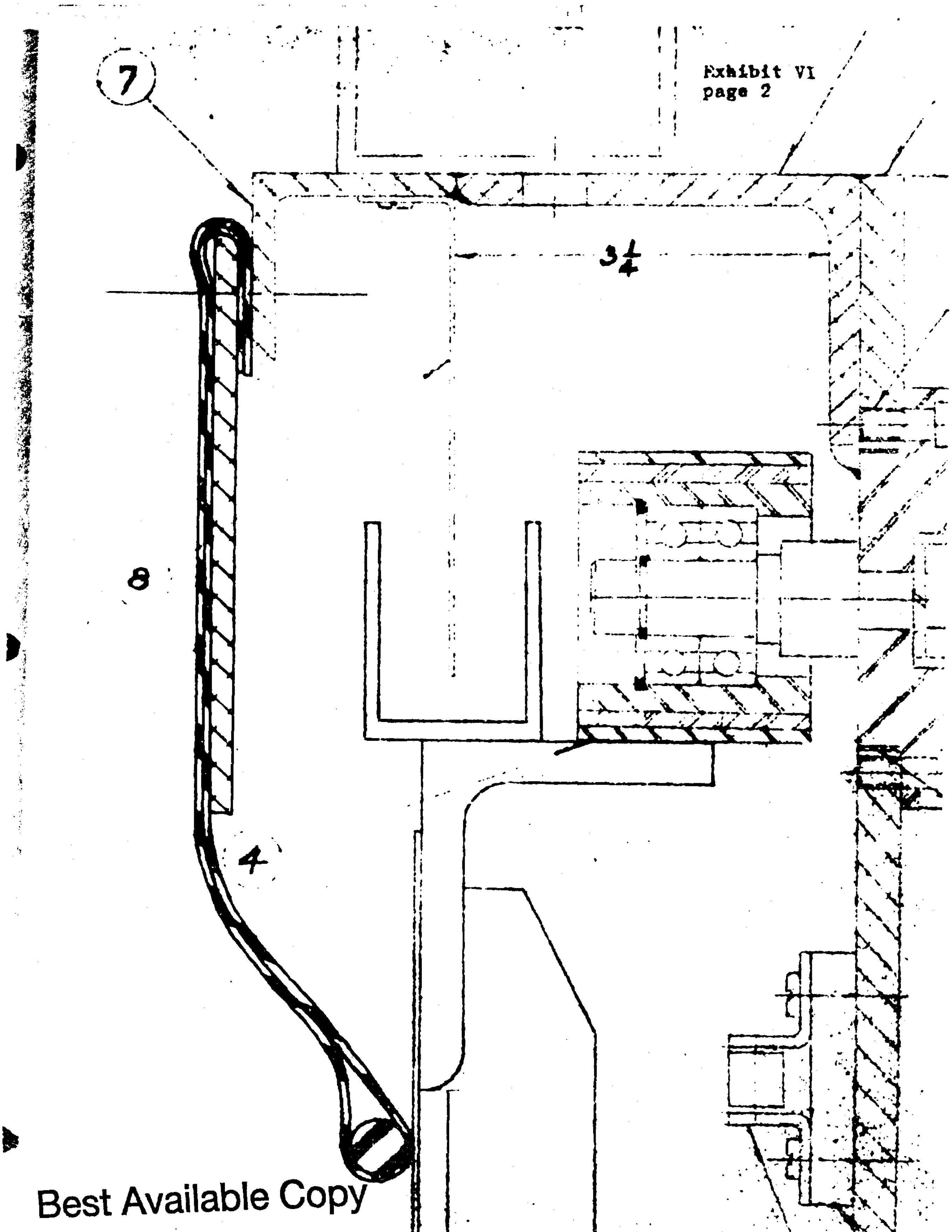
Exhibit VI
page 2



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